THE INTERLOCKING SUTURE.

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In 1903 the writer reported a modification of the Connell suture for end-to-end intestinal anastomosis.[1] In that paper attention was called to the results obtained in something over two thousand abdominal operations upon living dogs, performed at the Chicago Post-Graduate Laboratory of Anatomy and Operative Surgery, under aseptic conditions. In the discussion of the various forms of intestinal suture, mention was made of the fact that 35 per cent. of dogs died of a peritonitis resulting from leakage between sutures, in operations where the interrupted Lembert suture was used.

Later work has fully confirmed the above findings. It must be stated, however, that the large mortality in Lembert operations upon the dog does not apply to like procedures upon the human, the human peritoneum being much less susceptible to fatal peritonitis from leakage or infection than that of the dog, and while the interrupted Lembert has been practically abandoned in abdominal work upon the dog, yet that form of suture is still used upon the human intestinal tract with but an occasional death from peritonitis, the result of leakage.

The primary Lembert principle, that of inversion of cut edges and union of relatively broad peritoneal surfaces, has not, however, as yet been improved upon, improvement having been only in the manner of the application of that principle.

The first form of modification, that is, the Czerny-Lembert suture, is stronger and less liable to leakage than the Lembert alone, even when the Lembert is used in double rows.

The second modification form, the double Lembert (*i.e.*, Halsted's mattress suture) is not only more rapidly inserted, because of one knot for each two sutures, but it lessens the danger of leakage between sutures by exactly one-half, and so far as rapidity of insertion, strength, and safety are concerned, for general use on the human, it is perhaps the most practical application of the Lembert principle. As will be considered later, however, to insure against ordinary leakage, because of the longitudinal as well as lateral tension, the Halsted mattress sutures must be inserted much more closely together, than when the single Lemberts are used.

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[1] Modification of the Connell Suture, Journal of the Amer. Medical Assoc., March 7, 1903.

Wherever a continuous suture is advantageous, the continuous Lembert, (*i.e.,* the Cushing stitch, the Dupuytren modification, or the Richardson suture, in all of which the needle bites are taken not parallel but at right angles to the line of union), affords the greatest rapidity of insertion, as well as practical insurance against leakage, strength only, as in all continuous sutures, being the wanting factor.

In end-to-end intestinal anastomosis by the Connell method, the mortality in 400 operations upon dogs was reported by the writer, in 1903, as a trifle less than 3 per cent. In this recorded series the work was done by the Post-Graduate Faculty, by students working under a demonstrator, by independent investigators, and by students working alone. The mortality directly traceable to the Connell anastomosis in operations performed by experienced men was less than one-half of one per cent.

While the Connell operation apparently fulfils every indication in end-to-end anastomosis, yet it is not applicable to many operations encountered in visceral surgery. The Czerny-Lembert, the closely placed Halsted, the continuous Cushing, the Richardson, the double row of continuous overhand sutures, or the Murphy button fulfil nearly every other indication.

Conditions are encountered, however, in which not only strength of suture, but positive insurance against leakage is wanted; ease and rapidity of suture insertion, while desirable, being of secondary consideration.

As a fulfilment of this indication the writer devised and reported an interrupted interlocking mattress suture.[2] This suture is a modified Halsted, embodying all the advantages of the Lembert principle, and, if properly inserted, is absolutely proof against leakage.

Consideration of the ordinary Halsted sutures demonstrates (Fig. 2) that when the sutures are tied there is a pull in two directions, viz., at right angles to the line of union, and parallel to the line of approximation. It will be noted that in tying the knots, the spaces between sutures are increased, the danger and probability of leakage increasing accordingly. In fact, observation of operations upon dogs demonstrated that when single Lemberts and Halsted mattress sutures were inserted with equal spacing, the percentage of leakage peritonitis was greater with the Halsted than with the Lembert. To obviate this danger, and at the same time to utilize the clear advantages of the Halsted stitch, the halves of the Halsteds were placed slightly further apart, while the different

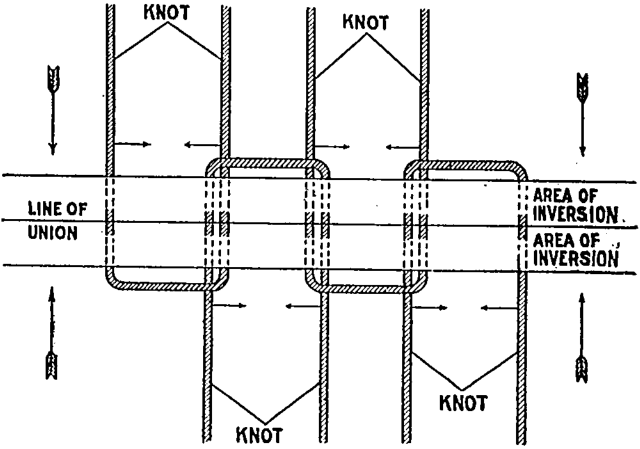

DIAGRAM 1.—Interlocking suture with knots alternating on each side of line of union Arrows indicate direction of suture tension. Lembert principle of inversion.

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[2] An Intestinal Suture, Journal of the American Med. Assoc., Jan. 27, 1900.

sutures were inserted as closely together as possible. As a result of this method, no leakage occurred in operations upon the small bowel; peritonitis resulted, however, in a few cases of colonic resection.

The next step was naturally an overlapping of the mattress sutures, and from this the interlocking stitch was evolved. In a word the interrupted interlocking suture is but the Halsted mattress suture, overlapped and interlocking, forming, when all knots are tied, a complete chain of stitches through which no leakage is possible. The suture can be inserted with knots alternating on each side of the line of union (Diagram 1) or with knots all on one side (Diagram 2). In either case but slight overlapping is necessary, though care should be taken in both instances that the first half of each succeeding suture passes *under the loop* and *over the loose end* of the suture immediately preceding, so that when all knots are tied a complete chain of stitches is formed (Figs. 1 and 3.).

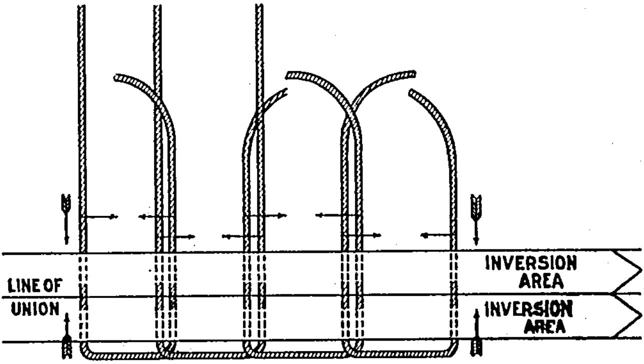
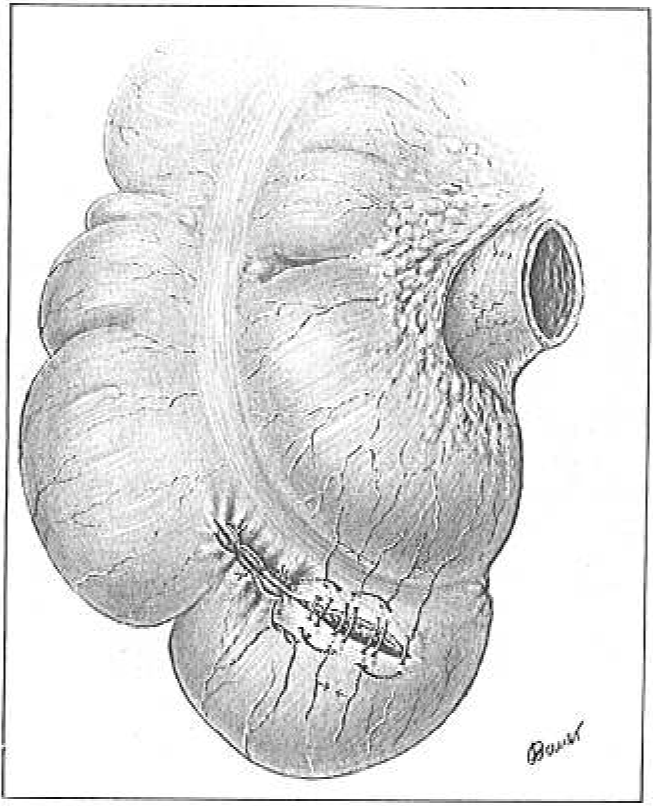


Diagram 2.—Interlocking suture with knots on one side of line of union. Arrows indicate direction of suture tension. Lembert principle of inversion.

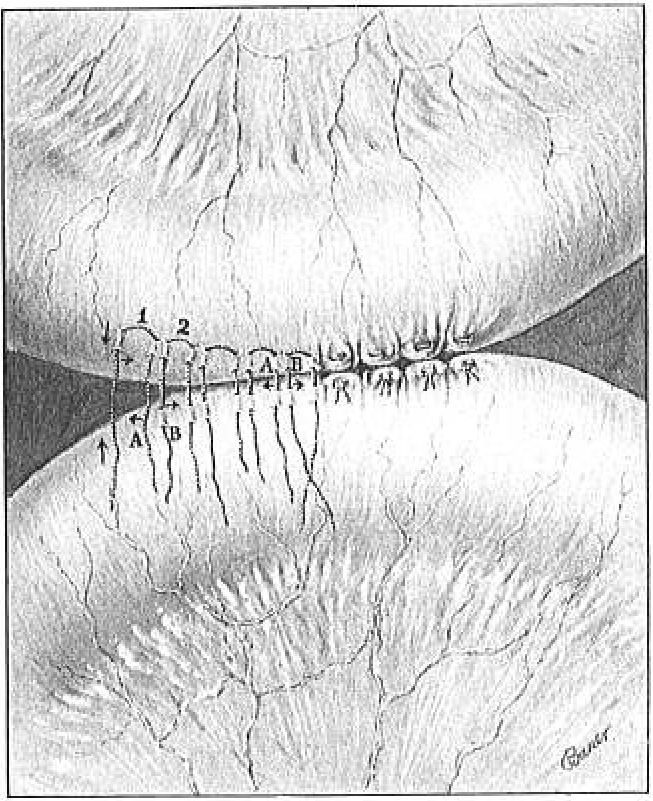
A glance at the diagrams, and consideration of the direction of suture tension as indicated by the arrowheads, demonstrates that there are no non-approximated points in the line of union, and that *stitch leakage,* barring a slough, is *entirely eliminated.* So far as strength is concerned, because of the

FIG. 1.



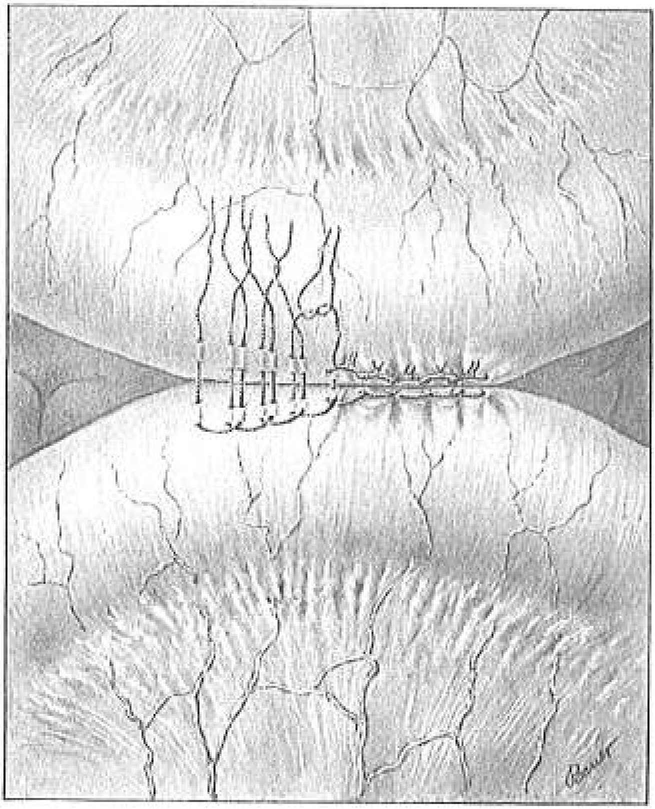
Closure with interlocking sutures. Alternating knots. This suture is simple and easy of insertion if it is remembered that all loose ends pass under the loops. The knots are purposely shown loosely tied, to more fully illustrate the interlocking chain arrangement.

Fig. 2.



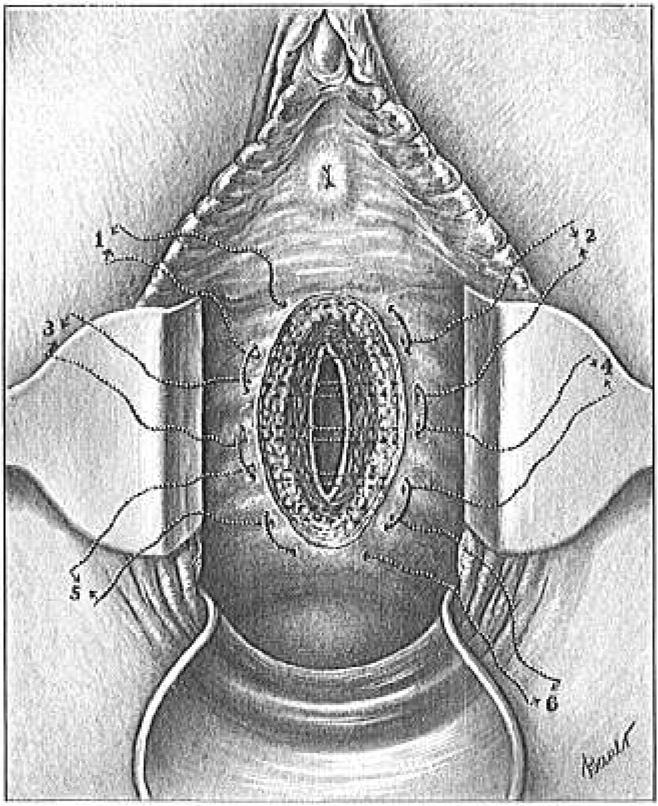
Halsted mattress sutures. Illustrating the manner in which spaces between sutures are increased upon tying the knots. This feature is exaggerated in the drawing to more fully bring out the weak points.

Fig. 3.



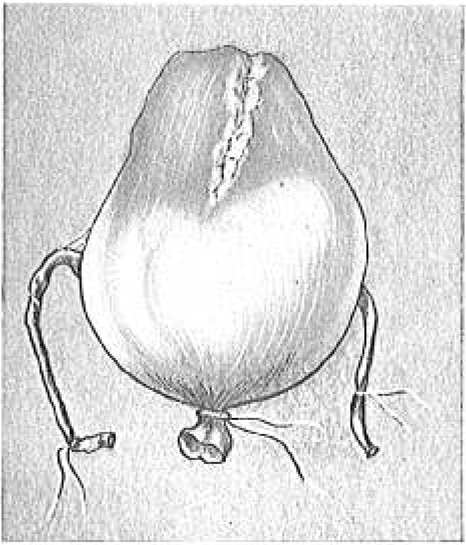
Interlocking suture with all knots on one side. Showing manner of insertion of loops, and crossing of loose ends to form the chain.

Fig. 4.



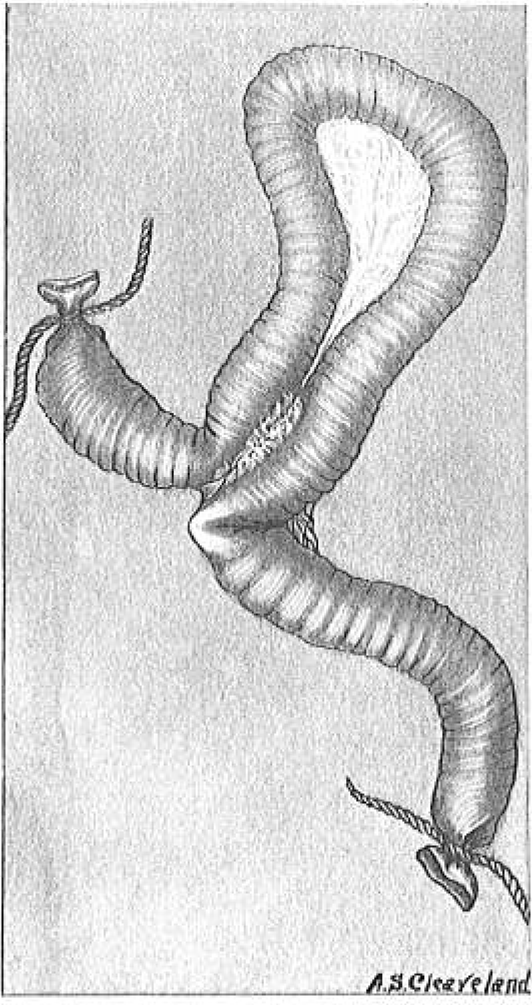
Closure of vesicovaginal fistula showing the interlocking suture inserted as in surface wound suturing, in such a manner as to approximate the raw edges without inversion.

FIG. 5.



Bladder of dog. Four weeks after resection and suture with interlocking stitch.

Fig. 6.



Bowel of dog. After lateral anastomosis with interlocking suture.

interrupted interlocking feature, the completed chain is obviously stronger than any other form of interrupted or continuous suture, each stitch supporting and being supported by its neighbors. While the interlocking suture is perhaps not as easily and rapidly placed as other forms of interrupted stitch, yet there is but little difference since one interlocked suture covers the ground of about three Lemberts, or one and one-half Halsteds. It is not possible to properly form the chain of stitches if each is tied as soon as taken. The first and second sutures are inserted, the first is then tied; the third inserted while the second is loose, the second then tied; the fourth inserted, the third tied, and so on, always tying one stitch behind.

The interlocking stitch may be applied as in ordinary surface wound suturing, without the Lembert inversion of cut edges, so that when the sutures are tied the cut edges will be approximated. Figure 4 is illustrative of this method of wound closure.

In an extended series of experiments upon dogs, in which operations were performed on stomach, pylorus, small intestine, colon, and rectum, in no instance did we find post-mortem or secondary operative evidence of leakage, and in no case did we find sloughing from suture pressure. I note three deaths from peritonitis in a series of 100, in none of which was leakage recorded, post-mortem evidence showing the peritonitis to be general and probably due to faulty technic and infection during the operation.

Twenty-five operations upon the bladders of dogs, varying from simple incision and closure with the interlocking suture, to removal of two-thirds of the viscus, showed no leakage and no deaths.

A series of experiments upon blood vessels with interlocking sutures of fine silk was begun, but unfortunately not completed owing to the writer's removal from Chicago. The results obtained, while not complete nor extensive enough for definite conclusions, were very promising and indicated that interlocking sutures may have a place in venous and arterial surgery.

The suture, while not necessary in a majority of alimentary tract operations, is peculiarly applicable to those conditions in which post-operative suture leakage is to be utterly eliminated, such as in certain operations upon cæcum, colon, and rectum. It is also of value in operations upon gall-bladder, ducts, urinary bladder, and blood-vessels.

The following cases of the writer are reported as illustrative of the range of applicability of this stitch:

CASE I.—*Suture of the Hepatic Duct After Removal of Large Stone.*—This case was reported in detail in ANNALS OF SURGERY for April, 1903.

Two stones were removed from an enlarged, elongated and distended gall-bladder, one from the cystic duct, and a non-faceted stone, weighing 250 grains, measuring one and three-fourths inches in length and three and one-fourth inches in circumference, was removed from the hepatic duct through an anterior longitudinal duct incision.

The liver was retracted upward, the stomach and duodenum were retracted downward and to the left, tension sutures were placed at each end of the hepatic duct incision, and the opening in the duct closed by the interlocking suture (with knots alternating). Drainage was established through the resected gall-bladder.

This case demonstrates that by proper visceral retraction and packing off, and by use of traction sutures to immobilize the part to be closed, the interlocking stitch may readily be properly inserted in any locality accessible to any form of interrupted or continuous suture.

CASE II.—*Suture of Bladder.*—Mr. B., age 38. Left bubonocele, large, right, partly strangulated and inflamed scrotal hernia.

The bubonocele on the left side was closed by the Ferguson anatomic method without incident. On the right side the usual skin incision was made, the aponeurosis of the external oblique recognized and split upward to fully expose the sac and canal. Sac appeared hypertrophied and in a high state of congestion and inflammation. In attempting to isolate and open the sac a gush of fluid, easily recognized as urine, showed that the bladder had been inadvertently opened. In freeing the bladder a partial prolapse of that viscus was demonstrated. The opening in the bladder was closed by one row of interrupted interlocking sutures (alternating knots) without Lembert inversion of edges. The sac was freed, and split up to the internal ring. The contained bowel and omentum, while highly congested, were not gangrenous, and were replaced in the abdominal cavity. The sac was removed and the operation completed as usual by the method of Ferguson. A few strands of silkworm gut were inserted as a drainage insurance.

Both wounds healed without incident, except for a slight superficial skin infection on right side. Drainage did not prove necessary. There was no urinary leakage, nor cystitis, nor at any time clinical indication that the bladder had been tampered with or irritated.

CASE III.—*Suture of Axillary Vein.*—Mrs. S., age 47. Operated in 1903 for extensive carcinoma of left breast, with marked involvement of glands in the axilla and in the subclavian triangle. A typical Halsted amputation was done,—the axillary space, the subclavian triangle, the space between them and beneath the clavicle were thoroughly cleared. Several enlarged axillary glands were attached to the axillary vein so closely as to necessitate sharp dissection. All were removed, however, without injury to the vein, except one near the clavicle. In removing this gland, a slightly ragged lateral hole was cut or torn in the vein, equal in length to a little more than one-third the circumference of the vein. Because of the high location of the tear, I wished to avoid ligation if possible.

A purse-string suture of fine silk was inserted, cut edges of vein inverted, and the suture tightened. This, however, so reduced the calibre of the vessel that the procedure seemed unwise; the purse-string, therefore, was removed and the opening in the vein closed by one row of interrupted interlocking sutures of fine silk. Lembert inversion (alternating knots). Upon relieving compression and allowing the blood-current to flow through the vein, no leakage was discernible, and no additional reinforcing sutures were necessary.

The skin incisions were closed as usual, and the patient was constantly watched for a period of three weeks. There were at no time symptoms of leakage from the sutured vein, nor more than the usual amount of drainage.

There was no œdema of the arm, no circulatory disturbance, and no venous congestion. The patient recovered without untoward symptoms, death occurring fourteen months later from local recurrence of the cancer, with general metastasis.

CASE IV.—*Typhoid Ulcer.*—Mr. R., age 32. Uneventful mild typhoid course for two weeks, when two slight hemorrhages occurred. In the early morning (4 A.M.) following he had a sudden sharp abdominal pain, seemingly more or less diffuse. After this subsided the patient remained fairly comfortable except for an occasional nausea and very moderate vomiting. The pulse and temperature rose during the forenoon and afternoon, the abdomen became tympanitic, with marked tenderness in the right lower quadrant. There were no symptoms of collapse. Blood count two days previously showed total leucocytes 6400, neutrophiles 76 per cent., small mononuclears 12 per cent., large mononuclears and transitionals 10 per cent., neutrophilic myelocytes 2 per cent. At 6 P.M. the day of the pain the total leucocytes were 18,200, neutrophiles 88 per cent., small mononuclears 4 per cent., large mononuclears and transitionals 8 per cent. Diagnosis was made of perforating ulcer, and operation performed fourteen hours after the attack of acute pain. An incision was made through the right rectus. A perforation was found in the ileum, approximately eleven inches from the ileocæcal valve. The opening was closed with one row of interrupted interlocking sutures of chromic gut (knots all on one side). No attempt was made to sponge more than the immediate vicinity of the ulcer. No irrigation or flushing was attempted, drainage was inserted, and the wound closed as rapidly as possible. The patient was placed in the Fowler position, and proctoclysis (Murphy) instituted. Reaction was prompt, the peritonitis did not become severe, and the patient recovered nicely from the immediate operation, later going to full recovery from the typhoid.

The blood findings in this case are pertinent, first, as regards prognosis. The prompt rise in neutrophilic cells showed that systemic reaction, and resistance to the peritoneal infection were active and strong, and hence lent a favorable aspect to the case; second, in view of the sudden neutrophilic hyperleucocytosis following the sharp abdominal pains, with rise of pulse, temperature and tympany, the diagnosis could scarcely be mistaken.

CASE V.—*Suprapubic Cystotomy and Perineal Section.*—Mr.

Y., age 47. A median perineal section was made for the removal of a large imbedded vesical calculus. The stone was loosened, crushed, and removed piecemeal through the perineal incision. The vesical mucosa was the seat of a papillomatous growth, and fearing malignancy a suprapubic incision was made and the bladder opened extraperitoneally. Removal of the growth and sharp curettage showing no apparent involvement of the vesical muscularis, the upper opening in the bladder was closed by one row of interlocking sutures without Lembert inversion, and drainage established *via* perineum.

The patient ran the usual course of convalescence without symptoms of note, eventually recovering with but slight chronic cystitis. Suprapubic wounds healed kindly. No leakage.

Case VI.—*Suprapubic Cystotomy.*—Mr. P., age 29. This patient had a vesical calculus, with apparently but a moderate cystitis. A suprapubic incision was made and the bladder opened extraperitoneally. The stone was removed, the vesical mucosa swabbed with a solution of nitrate of silver, thoroughly irrigated with hot boric solution, and because of the apparently good condition of the mucosa the bladder was closed with one row of interrupted interlocking sutures of formaldehyde gut (without Lembert inversion) without vesical drainage.

After operation the bladder was irrigated daily. The patient's immediate recovery was excellent. There was no sign of leakage, nor wound infection. While this case is illustrative of the prevention of leakage by the interlocking suture, yet an error was made in not establishing drainage, as is shown by the fact that cystitis persisted until I lost track of the case, a year later.

Case VII.—*Fecal Fistula.*—Mr. Le M., age 42. First operation April, 1903, for appendiceal abscess. An incision was made well outward toward the anterior superior spine. Cæcum, ileum, and omentum were found to be a mass of agglutinated adhesions, with marked chronic inflammation and hypertrophy. Pus was deep and completely walled off. In clearing the adhesions to get down to the pus, a hole an inch in length was torn in the cæcum. This was closed by a continuous Cushing suture of catgut. The pus was evacuated, and a Mickulitz gauze-rubber tube drain inserted. Drainage was profuse, and fecal matter was detected in the dressings on the fourth day. Patient recovered rapidly with the sinus still discharging fæces. The fecal discharge continued